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### ④ Television transmission system including a pyramidal coding/decoding circuit.

⑤ A pyramidal coding circuit comprises a decimation circuit (14.1) which receives the picture consisting of  $M \times N$  pixels to be transmitted and converts it into  $K + 1$  auxiliary pictures  $B_k$ , the numbers of horizontal and vertical pixels of  $B_k$  being smaller by respective factors  $A_H$  and  $A_V$  than those of the auxiliary picture  $B_{k-1}$  ( $k = 0, 1, 2, \dots, K$ ) preceding in ordinal number. Each auxiliary picture  $B_k$  is expanded in an expansion channel 14.4(.) to an expanded auxiliary picture  $B'_k$  having the same number of horizontal and vertical pixels as the auxiliary picture  $B_{k-1}$ . In a difference picture former 14.7(.) the auxiliary picture  $B_{k-1}$  and the expanded auxiliary picture  $B'_k$  having the same number of horizontal and vertical pixels as  $B_{k-1}$  are subtracted from each other for generating a difference picture  $D_{k-1}$ . The expansion channel has not only a two-dimensional interpolating low-pass filtering function 14.5(.) but also a picture prediction function 14.6(.)

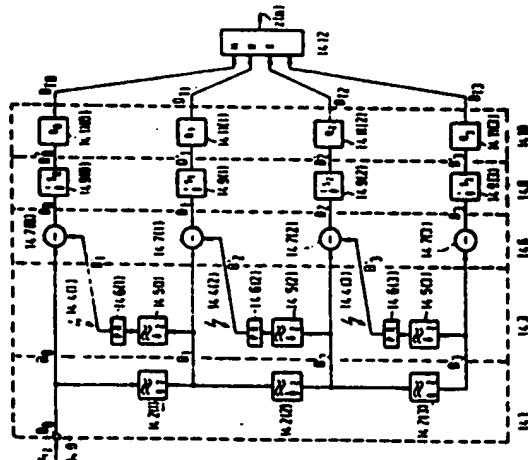


FIG.2

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interpolating low-pass filtering function.

Such a local expansion channel receives the auxiliary picture  $B_k$ , expands it to an expanded auxiliary picture  $B'_k$  whose numbers of horizontal and vertical pixels is equal to those of the difference picture  $D_{k-1}$ . In a circuit forming a sum picture this difference picture  $D_{k-1}$  and this expanded auxiliary picture  $B'_k$  are added together. Consequently the auxiliary picture  $B_{k-1}$  is obtained again. This auxiliary picture  $B_{k-1}$  is in turn expanded again and the expanded form is added to  $D_{k-2}$  so that the auxiliary picture  $B_{k-2}$  is obtained, etc. This operation is continued until the original picture  $B_0$  is obtained again.

The dynamic range of the difference pictures  $D_0$  to  $D_k$  will generally be much smaller than that of the auxiliary pictures. As a result, considerable fewer bits will be necessary for their coding than for the individual auxiliary pictures. It is even possible to further decrease the number of pixels of a difference picture to be transmitted. All these measures ensure that the total number of bits required to represent a complete picture is considerably lower than for the canonical picture.

15 B. Object and summary of the invention.

It is an object of the invention to provide a television transmission system including a pyramidal coding circuit and decoding circuit with which the total number of bits required to represent a complete picture can be still further decreased.

20 According to the invention a plurality of expansion channels in the pyramidal coding circuit and the local expansion channels in the pyramidal decoding circuit corresponding thereto have not only a two-dimensional interpolating low-pass filtering function but also a picture prediction function.

The Applicant has found that ascribing an additional picture prediction function to the expansion channel gives this channel such a transfer function that a considerable decrease is realised in the dynamic 25 range of the difference pictures, which in itself directly leads to a decrease of the bit rate.

A class of transfer functions suitable for this purpose is known as restoration or regularisation functions. This class of transfer function is extensively described in Reference 5.

Another class of transfer functions suitable for this purpose is described in section IV B of Reference 4 and in Reference 6.

30 In practice such an expansion channel can be implemented in different ways. For example, it can be implemented as a cascade arrangement of a two-dimensional interpolating low-pass filter and a suitably dimensioned two-dimensional picture prediction filter. In practical uses it will generally be preferred to combine both filters to a common filter.

35

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auxiliary picture  $B_1$  is supplied by the filter 14.2(1) and consists of an array of  $(M/2) \times (N/2)$  pixels. The auxiliary picture  $B_2$  is supplied by the filter 14.2(2) and consists of an array of  $(M/4) \times (N/4)$  pixels. Finally, the auxiliary picture  $B_3$  is supplied by the filter 14.2(3) and consists of an array of  $(M/8) \times (N/8)$  pixels.

The auxiliary pictures thus obtained are applied to an expansion circuit 14.3 which is constituted by

- 5 three expansion channels 14.4(.) receiving the respective auxiliary pictures  $B_1$ ,  $B_2$ ,  $B_3$ . Each expansion channel comprises a two-dimensional interpolating low-pass filter 14.5(.) with a two dimensional prediction filter 14.6(.) arranged in cascade therewith. The interpolating filters have a horizontal interpolation factor which is equal to the horizontal decimation factor  $A_H$  of the decimation filters and a vertical interpolation factor which is equal to the vertical decimation factor  $A_V$  of the decimating filters. The expansion channels
- 10 14.4(.) supply the respective expanded auxiliary pictures  $B'_1$ ,  $B'_2$  and  $B'_3$ . More particularly the expanded auxiliary picture  $B'_1$  consists of an array of  $M \times N$  pixels, the expanded auxiliary picture  $B'_2$  consists of an array of  $(M/2) \times (N/2)$  pixels and the expanded auxiliary picture  $B'_3$  consists of an array of  $(M/4) \times (N/4)$  pixels.

- 15 The auxiliary pictures  $B_0$ ,  $B_1$ ,  $B_2$ ,  $B_3$  and the expanded auxiliary pictures  $B'_1$ ,  $B'_2$ ,  $B'_3$  are applied to a circuit 14.6 forming a difference picture comprising four difference picture formers 14.7(.). Difference picture former 14.7(0) receives the pictures  $B_0$  and  $B'_1$  and supplies a difference picture  $D_0$  consisting of  $M \times N$  difference pixels. Difference picture former 14.7(1) receives the pictures  $B_1$  and  $B'_2$  and supplies a difference picture  $D_1$  consisting of  $(M/2) \times (N/2)$  difference pixels. Difference picture former 14.7(2) receives the pictures  $B_2$  and  $B'_3$  and supplies a difference picture  $D_2$  consisting of  $(M/4) \times (N/4)$  difference pixels. In addition to these difference pictures  $D_0$ ,  $D_1$ ,  $D_2$ , the circuit 14.8 forming the difference pictures supplies a difference picture  $D_3$  which is, however, identical to the auxiliary picture  $B_3$ .
- 20

- 25 Bit rate reduction is obtained by the fact that the dimensions of the difference pictures  $D_0$ ,  $D_1$ ,  $D_2$ ,  $D_3$  can be further reduced, for example, by a factor of  $S_0$ ,  $S_1$ ,  $S_2$ ,  $S_3$ , respectively, in both the horizontal and vertical direction. This operation can be realised by using a further decimation circuit 14.8 comprising four decimators 14.9(.) each receiving a different difference picture. This decimation circuit 14.8 supplies four modified difference pictures  $D'_0$ ,  $D'_1$ ,  $D'_2$ ,  $D'_3$ .

- 30 Since the dynamic range of the difference pixels will be smaller than those of the original pixels, a further reduction of the bit rate can be obtained by recoding, preferably non-linearly, of the difference pixels. To this end the modified difference pictures are applied to a recoding circuit 14.10 which in this embodiment comprises four recoding circuits 14.11(.). Each recoding circuit receives a differently modified difference picture and supplies the transmission pictures  $D_{T0}$ ,  $D_{T1}$ ,  $D_{T2}$ ,  $D_{T3}$  which are applied to a multiplexer circuit 14.12, and which supplies the series of transmission words  $z(n)$ . More particularly  $z(n)$  is obtained because the multiplexer circuit 14.12 each time first arranges the pixels of  $D_{T3}$  in series for each canonical picture, then those of  $D_{T2}$ , subsequently those of  $D_{T1}$  and finally those of  $D_{T0}$ .

- 35 In the interpolating filter 14.5(k) an operation is performed on the auxiliary picture  $B_k$  applied thereto, which operation is inverse to the operation performed by the corresponding decimating filter 14.2(k) on the auxiliary picture  $B_{k-1}$  applied thereto (see also Reference 1). The dynamic range of the difference pixels in the difference picture  $D_k$  and hence the number of bits which must be allocated to each difference pixel is mainly determined by the variations in brightness at transitions in the picture (edges).

- 40 By using the additional prediction factor 14.6(k) the expansion channel 14.4(k) can be given such a transfer function that an interesting bit rate reduction is realised. The transfer function can in fact be chosen to be such that the dynamic range of the difference pixels is considerably reduced.

- 45 As already stated, a class of transfer functions suitable for this purpose is known under the name of restoration or regularisation function. This class of transfer functions is extensively described in, for example, Reference 5.

- 50 Another class of transfer functions suitable for this purpose is described in section IV B of Reference 4. In this case stationary and non-stationary parts of the picture are separately subjected to an operation.

- 55 For the sake of completeness an example will be given of a transfer function associated with the class described in reference 5. To this end the transfer function of the two-dimensional decimating filter 14.2(k) will be denoted by  $A_0(\omega_x, \omega_y)$  and the transfer function of the expansion channel will be denoted by  $H_0(\omega_x, \omega_y)$ . In accordance with Reference 5 it holds that

$$(1) \quad H_0(\omega_x, \omega_y) = \frac{A_0(\omega_x, \omega_y)}{A_0^2(\omega_x, \omega_y) + p R(\omega_x, \omega_y)}$$

channel 24.7(k). This channel receives the local auxiliary picture  $B_k$  from the sum picture former 24.8(k) and applies the expanded local auxiliary picture  $B_k'$  to the next sum picture former 24.8(k). This local expansion channel, like the corresponding expansion channel in the pyramidal coding circuit (see Fig. 2), is adapted to perform a two-dimensional interpolating low-pass filtering function and a two-dimensional picture prediction function. In the embodiment shown the expansion channel 24.7(.) is therefore provided with a local two-dimensional interpolating low-pass filter 24.9(.) and a local two-dimensional picture prediction circuit 24.10(.). It is to be noted that a local expansion channel corresponds to an expansion channel in the pyramidal coding circuit if the two expansion channels supply principally the same expanded auxiliary picture.

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### E(3) Some alternative embodiments.

In the embodiment of the pyramidal coding circuit shown in Fig. 2 the decimation circuit 14.1 is constituted by a cascade arrangement of a plurality of two-dimensional decimating low-pass filters 14.1(.) whose horizontal and vertical decimation factors are equal to each other. In addition, the horizontal decimation factors are equal to the vertical decimation factors. Fig. 5 shows a decimation circuit 14.1 which is also constituted by a plurality of two-dimensional decimating low pass filters 14.12(.). These filters are parallel connected to the input 14.0 and the decimation factors of the filters are now mutually unequal. Again it has been assumed that the horizontal decimation factor of a filter is equal to its vertical decimation factor.

Fig. 6 shows a further embodiment of the pyramidal coding circuit shown in Fig. 2. It differs from the circuit shown in this latter Figure in that the expansion channel 14.4'(k) receives the transmission picture  $D_{Tk}$  for generating the expanded auxiliary picture  $B_k'$  and this expansion channel further comprises a local recoding circuit 14.13(k) and an interpolator 14.14(k). In the recoding circuit 14.13(k) an operation is performed on the pixels of the transmission picture  $D_{Tk}$ , which operation is inverse to the operation performed by the recoding circuit 14.11(k) on the pixels of the modified difference picture  $D_k$ .

The interpolator 14.14(k) has an interpolation factor  $S_k$  (both horizontally and vertically) and compensates for the operation of the decimator 14.9(k).

In the embodiments shown in Figs. 2, 4 and 6 each expansion channel has a picture prediction function. It appears in practice that those expansion channels receiving the auxiliary pictures of the smallest dimensions (for example 14.4(3)) need not have such a function because it yields a hardly noticeable improvement of the picture quality.

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### Claims

1. A television transmission system for the transmission of a picture consisting of  $M \times N$  pixels from a coding station (1) to a decoding station (2), the coding station comprising a pyramidal coding circuit provided with:
  - a decimation circuit (14.1) receiving the picture to be transmitted and converting it into  $K+1$  auxiliary pictures  $B_k$ , the numbers of horizontal and vertical pixels of the auxiliary picture  $B_k$  being smaller by respective factors  $A_H$  and smaller than those of the auxiliary picture  $B_{k-1}$  ( $k = 0, 1, 2, \dots, K$ ) preceding in ordinal number;
  - a picture expansion circuit (14.3) having  $K$  expansion channels each receiving a different auxiliary picture  $B_k$  and each being adapted to perform a two-dimensional interpolating low-pass filtering function for increasing the numbers of horizontal and vertical pixels of the auxiliary picture  $B_k$  applied thereto by the factors  $A_H$  and  $A_V$ , respectively, for generating an expanded auxiliary picture  $B_k'$ ;
  - a circuit (14.6) forming difference pictures receiving both the auxiliary pictures  $B_k$  and the expanded auxiliary pictures  $B_k'$  and subtracting the expanded auxiliary picture  $B_{k+1}'$  each time from the auxiliary picture  $B_k$  for generating difference pictures  $D_k$ ;
  - means (14.8, 14.10, 14.12) for converting the difference pictures  $D_k$  into series of transmission words  $(z(n))$ ; and in which the decoding station comprises a pyramidal decoding circuit (24) provided with
    - means (24.0, 24.1, 24.3) for converting the series of received transmission words  $z(n)$  into local difference pictures  $D_k$ ;
    - a local picture expansion circuit (24.5) comprising  $K+1$  local sum picture formers (24.8(k)) each receiving a different local difference picture  $D_k$  via a first input, an expanded local auxiliary picture  $B_k'$  via a second input and each supplying a local auxiliary picture  $B_k$  from their output, the numbers of horizontal

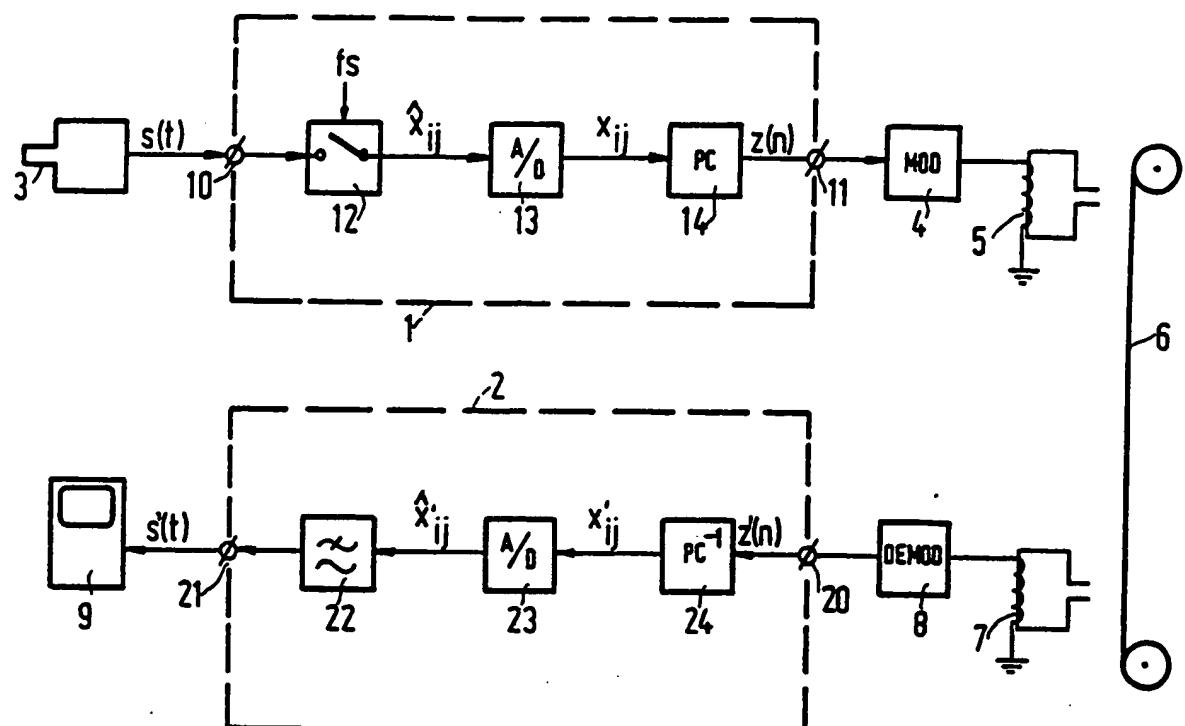


FIG.1

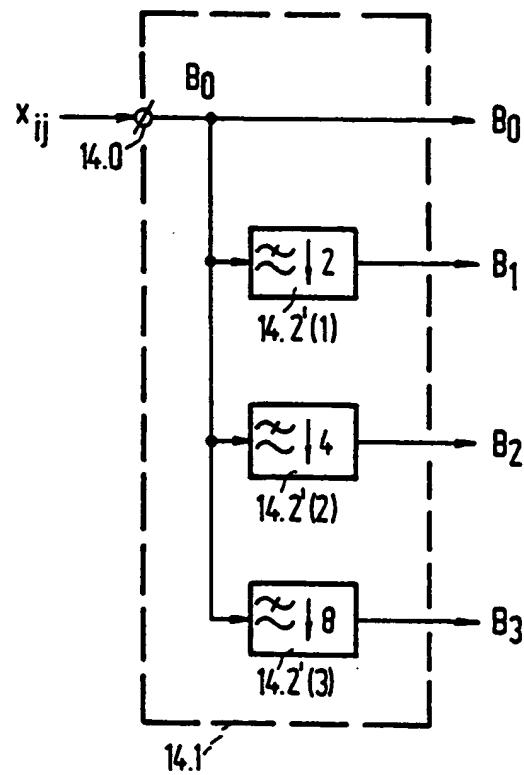


FIG.5

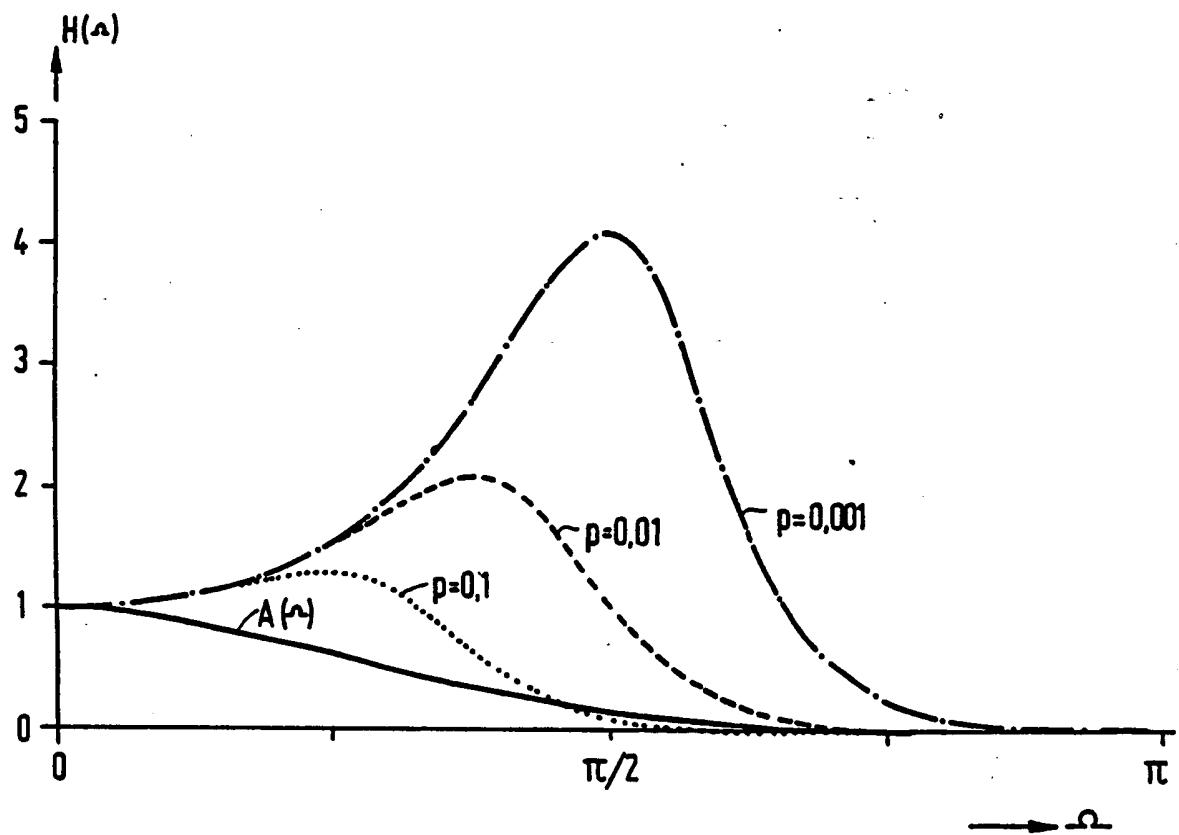


FIG. 3

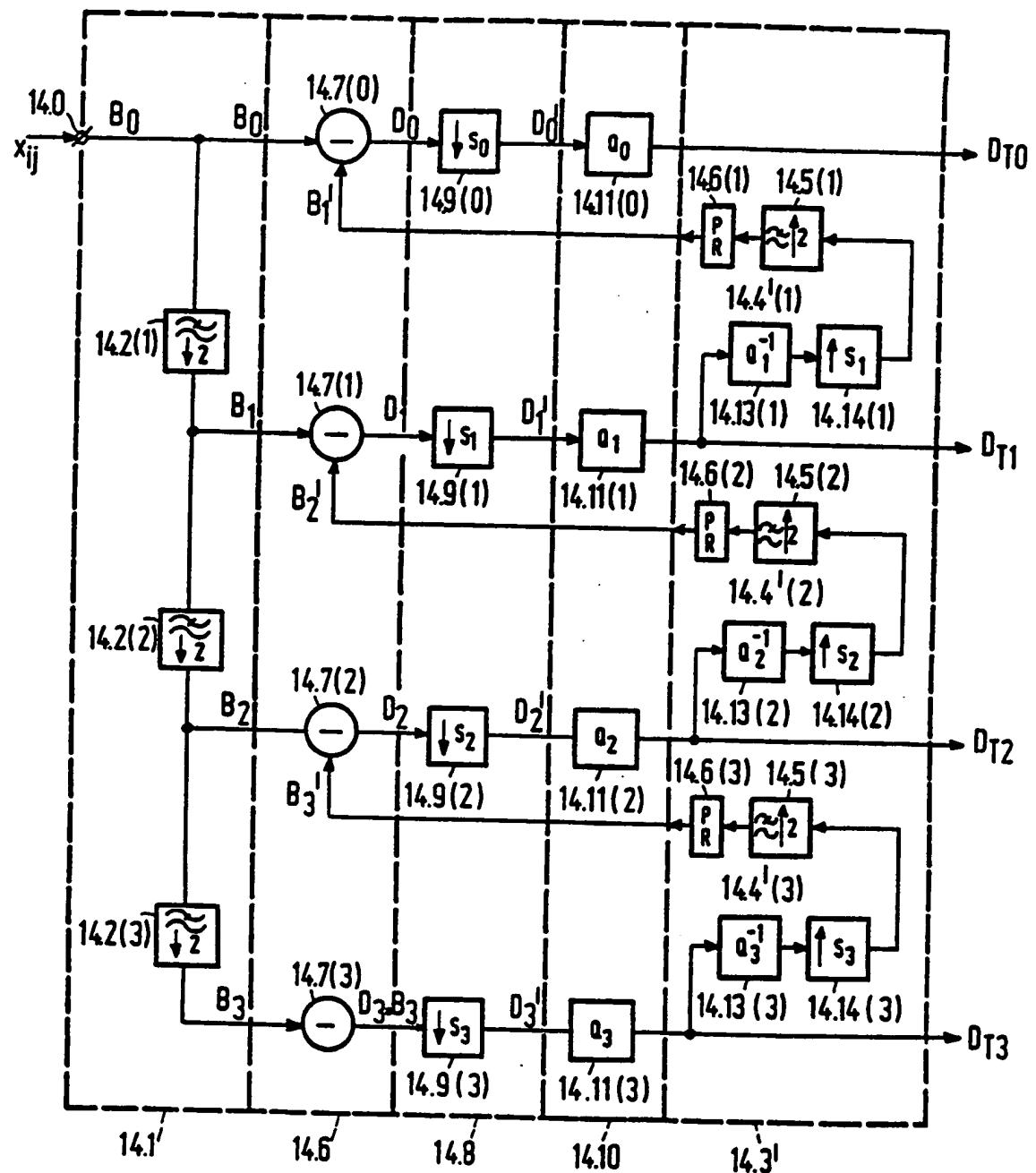


FIG.6

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